VERAGES
426/248
27
13

Antirachitic Properties of Irradiated Dry Milk

63

G. C. SUPPLEE, Ph.D.
AND
ODESSA D. DOW, M.S.
BAINBRIDGE, N. Y.

Reprinted from the American Journal of Diseases of Children
September, 1927, Vol. 34, pp. 364-371

COPYRIGHT, 1927
AMERICAN MEDICAL ASSOCIATION
535 NORTH DEARBORN STREET
CHICAGO

110A

ANTIRACHITIC PROPERTIES OF IRRADIATED DRY MILK*

G. C. SUPPLEE, Ph.D.
AND
ODESSA D. DOW, M.S.
BAINBRIDGE, N. Y.

The comparatively recent discoveries of Hess [1] and of Steenbock,[2] in which it was found that exposure to ultraviolet irradiation enhanced the antirachitic potency of certain antirachitically inactive substances, have been confirmed from other sources. Since milk is universally used in the infant dietary and because it is relatively ineffective as a specific for the prevention and cure of rickets, it is only natural that experimentation and clinical observations with irradiated milk should soon follow the discovery of the principle of activation. The reported clinical observations now available, even though limited, seem to agree that beneficial results accrue from the use of milk so treated.

Kramer [3] states that in a series of eight patients with active rickets the administration of irradiated milk produced healing in every case. Curative effects were observed at the end of the third week and were marked at the end of the fourth week. It was also observed that a greater retention of calcium and phosphorus resulted from feeding the irradiated milk. Cowell [4] found that after one month the roentgenograms of the wrists of children receiving 1 pint daily of irradiated milk which had been produced in the winter, showed decided improvement in calcification. Halac and Nassau [5] have shown that a high antirachitic value is imparted to raw milk by a brief period of irradiation. They assert that the rachitic condition of the children under observation was completely relieved in two or three weeks as a result of feeding irradiated milk. Mackay and Shaw [6] and György,[7] having used irradiated

*From The Research Laboratory of The Dry Milk Company, Bainbridge, New York.

1. Hess, A. F.: Experiments on the Action of Light in Relation to Rickets, Proc. Am. Pediat. Soc., June 7, 1924; abstr. in Am. J. Dis. Child. **28**:517 (Oct.) 1924.

2. Steenbock, H., and Black, A.: J. Biol. Chem. **61**:405, 1924.

3. Kramer, Benjamin,: Rickets in Infants, Am. J. Dis. Child. **30**:195 (Aug.) 1925.

4. Cowell, S. J.: Brit. M. J. **1**:594, 1925.

5. Halac, E. E., and Nassau, E.: Ztschr. f. d. ges. phys. Therap., 1926, vol. 31.

6. Mackay, H. M. M., and Shaw, H. F.: Brit. M. J. **2**:344, 1925.

7. György, P.: Klin. Wchnschr. **5**:747, 1926.

dry milk, asserted that it was a potent factor in curing uncomplicated rickets. The latter observes that once dry milk is irradiated it retains its full potency for long periods of time.

The antirachitic activation of milk to a degree that renders it a reliable prophylactic material for diets used in the prevention of rickets is a subject that presents manifold possibilities. Hess and Unger [8] and others quoted by them have come to the conclusion that 50 per cent or more of the children of the poorer classes are affected with rickets to a greater or less degree. The prevalence of the disease, therefore, warrants serious consideration of any prophylactic measures that may be readily adaptable for general application. Irradiated foodstuffs, and particularly milk, seem to suggest a source of greater potential benefit, easily obtained, than is to be expected by the now generally accepted procedures for combating the disease. The proved merits of cod liver oil, direct exposure to sunlight and the bodily exposure to the rays of the quartz mercury vapor lamp are known to be potent methods for the suppression of rickets, but universal application of these methods is of necessity restricted. Furthermore, the investigations of Steenbock and Black [9] indicate that a comparatively low level of the antirachitic factor extended over a long period of time may be preferable to a high level for only a short period of time. On the basis of these observations, the advantages of feeding infants a prophylactic dietary of irradiated milk over the relatively long period in which milk is fed is at once obvious.

The antirachitic fortification of milk to supply all bottle fed infants is a procedure that cannot be readily adapted for home use, nor is the procedure a practicable one for the majority of practitioners. Therefore, up to the present time the feeding of irradiated milk has been confined to hospitals and institutions in which equipment and personnel are available for the proper preparation of the product. Such limitations will of necessity prevent a wide dissemination of the benefits known to result from the use of activated milk and, unless the principle is applied to a suitable and easily accessible preparation, many infants will be deprived of a needed prophylactic of rickets. While irradiated dry milk has been prepared experimentally for clinical observations, it has been only recently that the principle of irradiation has been utilized for mass production of this product.[10] In the commercial production of antirachitically activated dry milk, certain objectionable features, which manifested themselves in the early experimental methods of

---

8. Hess, A. F., and Unger, L. J.: Seasonal Variations of Rickets, Am. J. Dis. Child. **22**:186 (Aug.) 1921.

9. Steenbock, H., and Black, A.: J. Biol. Chem. **64**:263, 1925.

10. The dry milk referred to is known as Dryco brand.

irradiation, appear to have been overcome. These objectionable features, namely, the development of a disagreeable taste and odor, and possible destruction of vitamin A, were undoubtedly due to the lack of recognition of certain factors now known to be important for the proper treatment of the product. The avoidance of over-exposure to the rays of short wave length, and the application of a perfected technic of irradiation has been intimated by Kramer [3] and appears to have been applied, on a limited scale at any rate, by Halac and Nassau.[5]

TABLE 1.—*Percentage of Ash in Long Bones of White Rats Fed Variable Quantities Of Irradiated and Nonirradiated Milk*

Rachitic Ration with	2 Cc. Daily	4 Cc. Daily	7 Cc. Daily	9 Cc. Daily	15 Cc. Daily
Nonirradiated Dry Milk	43.55	45.55	47.29	52.80	55.61
Irradiated Dry Milk	49.00	53.07	55.18	58.22	60.09

TABLE 2.—*Comparative Antirachitic Properties of Irradiated And Nonirradiated Dry Milk* *

Rat No.	Amount Reconstituted Dry Milk per Day (Cc.)	Treatment of Dry Milk	Per Cent Ash in Humeri	Roentgenograms	Costochrondral Junctions
873	1	Nonirradiated	45.07	Rickets marked	Much enlarged
888	1	Irradiated	49.04	Rickets moderate	Enlarged
918	2	Nonirradiated	44.97	Rickets marked	Much enlarged
936	2	Irradiated	48.89	Rickets slight	Slightly enlarged
875	4	Nonirradiated	48.80	Rickets slight	Slightly enlarged
890	4	Irradiated	56.00	Rickets negative	Normal
847	4	Nonirradiated	42.65	Rickets moderate	Enlarged
859	4	Irradiated	52.77	Rickets slight	Slightly enlarged
927	4	Nonirradiated	45.85	Rickets moderate	Enlarged
942	4	Irradiated	53.82	Rickets very slight	Slightly enlarged
1037	4	Nonirradiated	43.55	Rickets moderate	Enlarged
1048	4	Irradiated	55.04	Rickets trace	Normal
881	9	Nonirradiated	54.14	Rickets moderate	Slightly enlarged
895	9	Irradiated	59.52	Rickets negative	Normal
851A	9	Nonirradiated	54.84	Rickets moderate	Enlarged
865	9	Irradiated	60.29	Rickets negative	Normal
901	9	Nonirradiated	54.44	Rickets moderate	Slightly enlarged
1018	9	Irradiated	61.62	Rickets negative	Normal
1042	9	Nonirradiated	54.24	Rickets slight	Slightly enlarged
1055	9	Irradiated	59.93	Rickets negative	Normal
884	15	Nonirradiated	62.33	Rickets negative	Normal
900	15	Irradiated	62.43	Rickets negative	Normal
856	15	Nonirradiated	54.08	Rickets slight	Normal
867	15	Irradiated	63.03	Rickets negative	Normal

* These results were from different samples of the irradiated and nonirradiated dry milk obtained at intervals through a period of eighteen months.

RESULTS FROM IRRADIATED DRY MILK

The dry milk to which reference has been made is a product desiccated by the revolving double cylinder process and contains 12 per cent of butter fat. Its antirachitic and calcifying properties are enhanced by exposing the product to the rays of the quartz mercury vapor lamp in a manner which permits practically the entire surface area of any given particle of milk solids to remain within the activating influence of the rays for a brief period, which is estimated to be approximately one minute. The degree of antirachitic potency and calcifying properties

imparted to this product is best determined by comparing the results obtained with the product before and after application of the method of irradiation to which it is subjected. The results of such comparisons are shown later in this paper. White rats were used for all comparative studies, and the laboratory methods were carried out according to standard and recognized procedures. Varying quantities of the irradiated and nonirradiated dry milk were fed in conjunction with a rachitic ration [11] for a period of forty-eight days, at the end of which time the long bones were analyzed for ash content, roentgenograms of representative specimens of each group were obtained,[12] and autopsies were performed on all experimental animals. In making the determinations of bone ash, the procedure recommended by Bethke, Steenbock and Nelson [13] was followed. The ash content of the bones, therefore, is expressed on the water and fat free basis.

From 219 individual comparisons with the irradiated and nonirradiated product fed under identical conditions, the results shown in table 1 were obtained. In table 2 are shown some of the results obtained with the irradiated and nonirradiated dry milk, using the ash content of the bones, the roentgenograms and the condition of the costochrondral junctions as the basis for comparison.

VITAMIN POTENCY OF IRRADIATED DRY MILK

On the basis of preliminary experiments with irradiated milk, reports of which have been published to date, there has been some consideration of the possibility of destruction of vitamin A. Titus, Hughes, Henshaw and Fitch [14] claim that vitamin A is materially decreased in the irradiated milk. Their method of irradiation was to expose a layer of milk 2 mm. in depth at a distance of from 18 to 20 inches from the light. A personal communication from one of the authors states that the milk was irradiated for twenty minutes. Spinka [15] asserts that vitamin A is not destroyed by an exposure of twenty minutes to the ultraviolet rays but that the ozone generated by the lamp brings about detrimental results. He states that these results are not manifested when air is excluded from the product during irradiation. From these data, it would appear

11. Sherman, H. C., and Pappenheimer, A. M.: Proc. Soc. Exper. Biol. & Med. **18**:193, 1920-1921.

12. The roentgenograms were prepared and interpreted by Dr. A. F. Hess and Dr. Charles Gottlieb of New York.

13. Bethke, R. M.; Steenbock, H., and Nelson, M. T.: J. Biol. Chem. **58**: 71, 1923.

14. Titus, R. W.; Hughes, J. S.; Henshaw, W. R., and Fitch, J. B.: J. Ind. and Eng. Chem. **18**:843, 1926.

15. Spinka, J.: Biochem. Ztschr. **153**:197, 1924.

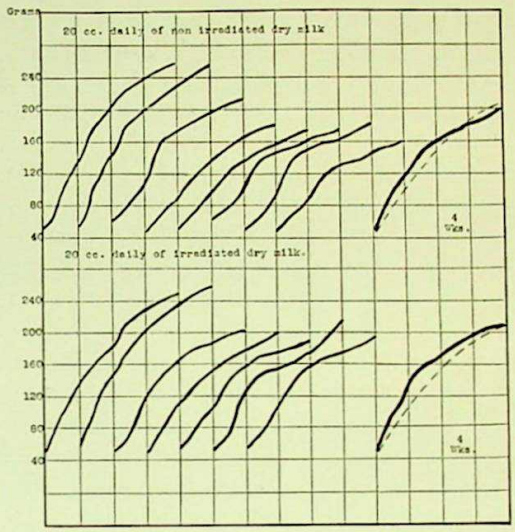

Fig. 1.—Growth curves of white rats receiving 20 cc. daily of irradiated and nonirradiated dry milk as the sole source of vitamin A. The results show that there is no impairment of vitamin A in the irradiated product. The curve at the extreme right is a composite curve for the group, compared with the normal curve.

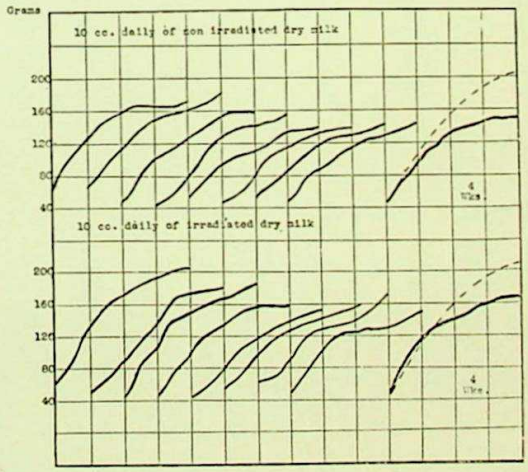

Fig. 2.—Growth curves of white rats receiving 10 cc. of irradiated and nonirradiated dry milk as the sole source of vitamin A. Even though 10 cc. of the irradiated or nonirradiated products is insufficient to furnish adequate vitamin A for normal growth, the results show that there has been no impairment of vitamin A in the irradiated product. The curve at the extreme right is a composite curve for the group compared with the normal growth curve.

that there is no definite proof that vitamin A is destroyed by irradiation per se. In order to determine whether vitamin A was destroyed in the dry milk irradiated with suitable precautions, several experimental studies have been conducted with the irradiated and nonirradiated product. Figures 1 and 2 show the growth obtained by feeding white rats 10 and

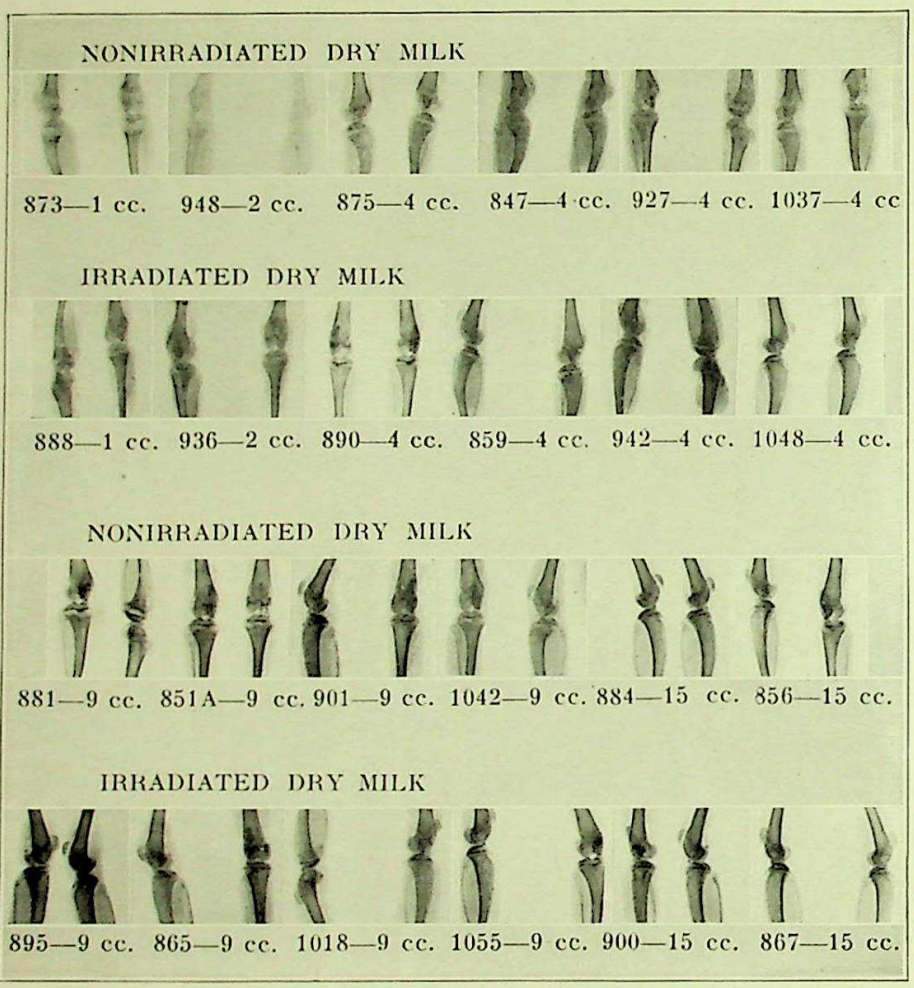

Fig. 3.—Roentgenograms of joints of white rats which have received irradiated and nonirradiated dry milk.

20 cc. quantities daily of the treated and untreated dry milk as the sole source of vitamin A. From these results it appears that there is no impairment of growth due to decreased fat soluble vitamin content of the irradiated product. In fact, the composite growth curve for the respective groups shows that the irradiated product allows better growth than

the nonirradiated product. This result is presumably due to increased antirachitic properties. Further tests conducted with this product wherein the body store of vitamin A was first depleted by feeding a vitamin A free ration for from six to eight weeks showed that when either the irradiated or nonirradiated dry milk was fed in 5 and 10 cc. quantities daily, as the sole source of this factor, growth was resumed within a short time. The severe xerophthalmia that developed during the period in which vitamin A was not given was completely cured—in the majority of cases, within from ten days to two weeks. The fact that no distinguishable difference was observed in the results from irradiated and nonirradiated material indicates that the method of treat-

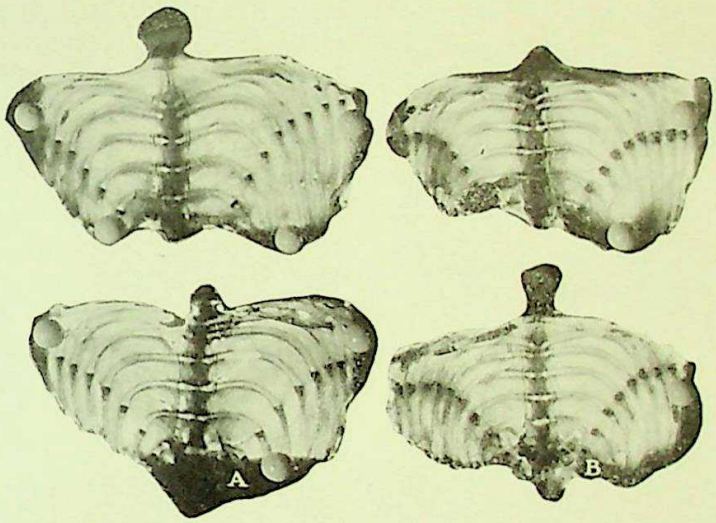

Fig. 4.—Ribs of white rats showing differences in costochondral junctions resulting from feeding irradiated and nonirradiated dry milk. *A*, after use of irradiated dry milk, showing normal costochondral junctions; *B*, after use of nonirradiated dry milk, showing enlarged costochondral junctions.

ment as applied to this product has not measurably affected its vitamin A potency. The foregoing studies were all conducted with milk produced in winter.

Since the oxidizing effects of ozone have been cited as detrimental to irradiated milk, tests were conducted to ascertain if such a result was manifested by destruction of vitamin C in the product under consideration. Eighty cubic centimeters of the reconstituted irradiated and nonirradiated dry milk were fed to guinea-pigs daily as the sole source of the antiscorbutic factor. The results showed that during an experimental period of sixteen weeks no symptoms of scurvy were manifested in the animals receiving either product. The animals in each group grew equally well, and autopsy revealed no significant pathologic conditions indicating unfavorable action by the irradiated product.

COMMENT

The favorable results obtained with dry milk irradiated with ultraviolet rays, from the standpoint of laboratory studies, indicate that nutritive and therapeutic properties of the product are enhanced to an appreciable degree. It appears that the beneficial results known to accrue to food products exposed to ultraviolet rays can be attained without measurable destruction of the readily oxidizable vitamins A and C, provided that a suitable technic of irradiation is used. Critical studies of the product under consideration have shown that there is no evidence of a disagreeable flavor and odor commonly found in milk products that are exposed to the ultraviolet rays for long periods of time. Furthermore, the usual keeping qualities of the product are apparently unimpaired. The irradiated product has been found to keep satisfactorily and apparently in its original condition for a period of several months. The comparative studies which have been made indicate that the process of activation as applied does not accelerate oxidation of the fatty constituents to a degree that impairs the nutritive value or in any way induces changes of a detrimental character.